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INVESTIGATION OF THE METHOD OF EFFECT ON CONVECTIVE CLOUDS WITH--ETC(U)
JAN 78 Y Y KORNIYENKO, M V TOVBIN, A I FURMAN

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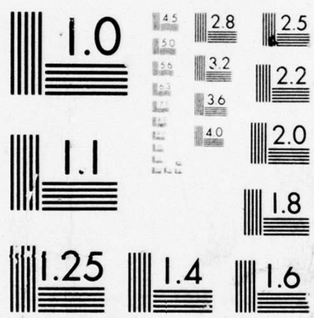

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INVESTIGATION OF THE METHOD OF EFFECT ON CONVECTIVE CLOUDS WITH THE AID OF SURFACE ACTIVE COMPOUNDS

by

Ye. Ye. Korniyenko, M. V. Tovbin, A. I. Furman

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By: Ye. Ye. Korniyenko, M. V. Tovbin, A. I. Furman

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U. S. BOARD ON GEOGRAPHIC NAMES TRANSLITERATION SYSTEM

Block	Italic	Transliteration	Block	Italic	Transliteration
А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

INVESTIGATION OF THE METHOD OF EFFECT ON CONVECTIVE CLOUDS WITH THE AID OF SURFACE-ACTIVE COMPOUNDS.

Ye. Ye. Korniyenko, M. V. Tovbin, A. I. Furman.

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During the development of the methods of the artificial causing of precipitation, as under the influence on other weather processes, main condition is at present the detection of those component/links of the process of the formation of the precipitation in which with the aid of microeffects it is possible to obtain macroscopic effect. This condition is caused by the facts that energy of precipitation-forming processes considerably exceeds the energy possibilities of contemporary technical means [5]. The difficulty of developing the effective methods of the causing of precipitation is caused also by the facts that the question concerning the mechanism of the natural processes of precipitation formation still distant at present from solution.

One Of the possible mechanisms of the formation of precipitation

in convective clouds is proposed Langmuir [2] the chain/catenary process of the fragmentation of large drops.

In cumulus congestus clouds, as a rule, is contained certain quantity of large drops of water. Falling under the action of the force of gravity, such drops seize in their way cloud particles (gravity coagulation); gradually increasing in size/dimensions. With the specific "critical" dimension, namely, after achieving a radius of approximately 3 mm, drop it becomes unstable and spontaneously it decomposes to smaller drops. The latter are transferred by the ascending currents to the upper part of the cloud. In this case, they also increase, reaching the size/dimensions at which the ascending currents no longer can support them in suspension. Further such particles again begin to be omitted, gradually increasing to critical dimensions. As a result of the multiple repetition of the described process, occurs the dispersive rearrangement of cloud, a quantity of large particles in it continuously grow/rises, which as the final result is led to precipitation. The possibility of development in the cloud of chain/catenary process as showed Langmuir, is determined in essence by his vertical power/thickness and liquid-water content.

On the basis of approximate computations, it is possible to show that the mechanism of the chain/catenary fragmentation of drops under natural conditions can occur only in the clouds whose vertical extent

about 7 km and average liquid-water content are not less than 1 g/m^3.

Taking into account foregoing, during the development of the method of the causing of precipitation from convective clouds, one ought not to have provided artificial effect precisely on the chain/catenary process of the fragmentation of large drops.

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In other words, it is necessary to explain the possibility of the boosting of the process of the fragmentation of drops in clouds and artificial to create such conditions under which chain/catenary process can be developed in the clouds of smaller power/thickness.

For explaining this possibility, one should examine the factors on which depends the development in the clouds of the chain/catenary process of the fragmentation of drops. By such by factors, as noted above, are first of all vertical extent and water content of clouds. However, to affect artificially these parameters is not represented at present possible.

Furthermore, the development of the chain/catenary process of the fragmentation of drops depends on their critical dimension. In connection with this arises the question concerning the possibility

of artificial effect on the critical dimension of the spontaneously crushing drops, decreasing which, it is possible to cause chain/catenary process in the clouds of smaller power/thickness and liquid-water content.

For the calculation of the critical dimension of the crushing drops V. G. Levichem [1] was formed an equation

$$r_{\kappa} = \frac{A\sigma}{\rho v^2}, \quad (1)$$

where r_{κ} is a critical radius of crushing drop, v - the rate of its incidence/drop, ρ - air density, σ - surface tension on boundary liquid - air, A - a constant value.

Equation (1), as it was shown one of the authors of present article [4], it will agree well with experiment.

As can be seen from the equation of Levich, the size/dimension of the spontaneously crushing drops is proportional to the surface tension of liquid. This makes it possible to outline the way artificial change r_{κ} and thereby, artificial effect on the development of the chain/catenary process of the fragmentation of drops in clouds. So, the impurity/admixtures of surface-active compounds PAV [surface-active agent]) are capable sharply (2-2.7 times) to reduce the surface tension of water and respectively

to decrease a radius of the spontaneously crushing drops, this must create favorable conditions for development in the cloud of the chain/catenary process which can give rise to of precipitation. In this case,, as showed the calculations of B. V. Kiryukhin, for developing the chain/catenary process, the required minimum power/thickness of cloud composes altogether only 3-4 km with liquid-water content of approximately 2 g/m^3.

On the basis of the indicated considerations was placed the problem - develop the method of the artificial causing of precipitation from the clouds of a comparatively low power/thickness. It is necessary to keep in mind that the proposed method makes it possible to give beginning to the process of the formation of precipitation, for the addition/completion of drop-forming fraction in cloud, the method effect does not have.

In connection with this the application/use of the developed method could give noticeable practical effect first of all in the clouds of considerable power/thickness. However, the field testing of its effectiveness it was solved to fulfill on the clouds of a comparatively low power/thickness for following reasons.

First of all it is necessary to establish/install that "does wear/operate" method generally. This testing is most better carried

out on clouds whose probability of chain/catenary process under natural conditions is small. Incidentally is eliminated the effect of crystallization on the formation of precipitation; let us note that in the steppe part of the Ukraine where it was assumed to carry out experiments, clouds whose power/thickness is are more than 4 km, as a rule, have temperature at the height/altitude of apex/vertex below -10°.

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It is of also interest, is it possible with the aid of this method to obtain virtually significant settlings in the indicated area, which possesses the determined resource/lifetimes of clouds Cu cong, which do not overgrow naturally in Cb.

Finally, the available technical capabilities (aircraft of IL-14) did not make it possible to carry out experiments on the clouds of considerable vertical power/thickness.

With those, in order to enlarge the possibilities of applying the method, namely, artificial to increase the rate of growth of the drops, which contain PAV, to the selected reagent was added urea - the hygroscopic substance, virtually not decreasing the effect PAV on the surface tension of water.

Field tests of reagent were carried out by summer 1956 in the steppe areas of the Ukraine, part of the experiments in the Black Sea coast of Caucasus.

The fault of reagent into cloud was realized with the aid of the aircraft liquid installation, ensuring the expenditure/consumption of 11 l/s, through delivery pipe with a diameter of 15 cm. In relative wind, the jet of reagent was crushed and in the form of small drops fell into cloud. Reagent was introduced during the flight/span of aircraft in cloud deck (on 100-200 m its lower than upper boundary) in a quantity 10-15 l on km^3 of the volume of cloud.

After gulf/bay the aircraft descended under the basis/base of experimental cloud and was located here prior to the beginning of precipitation and during entire time of their precipitation. Was record/fixed time of the beginning of precipitation, their duration and intensity (visually) on gradations "separate drops", "weak rain", the "moderate rain".

Effects were carried out into the second half summer/years under diverse synoptical conditions. As a rule, near experimental clouds were located Cb, the given natural settlings.

Parameters of the clouds, subjected to effect, and the results of experiments are given in Table 1.

As can be seen from these tables, the vertical extent of clouds was located 2130-4190 m, in this case in 11 cases of 15, it exceeded 2500 m. Temperature at the height/altitude of seeding was almost in all experiments is negative but in the majority of cases, it did not exceed -10°. All clouds at the torque/moment of effect increased.

From experimental clouds, as a rule, fell the precipitation in the form of separate drops or weak rain.

The evaluation of the effect of actions only according to data on the precipitation Lake of experimental clouds is difficult, since from these clouds with the determined probability could fall the natural settlings. This fact can be excluded by carrying out control experiments without effects on analogous clouds. The comparison of precipitation from experimental and control clouds will give the characteristic of the effect of actions. According to this pattern at present in UkrNIGMI is made the evaluation of the effect of actions on convective clouds by solid CO_2.

However, conducting control experiments would lead to a considerable increase in the volume of work, and the solution of posed problems would require much time. Therefore to evaluate it was solved to utilize materials of 32 experiments on control clouds, the carried out according to program effects by solid CO_2. So that this comparison would be competent, it is necessary that the parameters of experimental and control clouds, determining the process of precipitation formation, would be close between themselves.

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By such by the parameters first of all is the vertical extent of cloud and the temperature at the level of the effect, last/latter determines the possibility of the natural formation of precipitation because of berzherona - Findeisen's process. Let us note that of control clouds this value was measured just as in experimental, i.e., during the entrance into cloud at height/altitude 100-200 m lower than upper boundary.

Table 2 and 3 gives the frequency of the values of these parameters of experimental and control clouds.

The analysis of data of tables shows that the experimental clouds had somewhat a large power/thickness; however, were more warm

than controls. This is confirmed on the average values of the parameters in question: average vertical power/thickness is equal to 3030 m of experimental and 2840 m of control clouds, mean temperature on level of effect -5.8 and -7.3° respectively.

Table 1. Parameters of experimental clouds and the results of the effects by the reagent of VZhS + urea.

(1) Дата	(2) Район	(3) Время залива (час., мин.)	ВГ (м)	НГ (м)	ΔH (м)	(4) $t_з$ (град.)	(5) Скрытый период осадкообразования (мин.)	(6) Общая продолжительность осадков (мин.)	(7) Продолжительность дождя (мин.)	(8) Характер осадков
24 VI	(9) Кишинев	15 22	5340	1230	4110	—11,7	10	30	30	(10) д
28 VI	(11) Кривой Рог	15 40	3960	1140	2820	—4,7	9	11	10	(12) д, к
5 VII	(13) Тоже	14 15	4680	2090	2590	—5,9	6	53	27	(14) к, д
5 VII	"	15 59	4760	2320	2440	—6,2	(15) Осадков не было			
5 VII	"	18 10	4660	2530	2130	—3,5	9	27	—	(16) к
22 VII	"	14 04	6050	2500	3550	—11,0	(15) Осадков не было			
24 VII	(17) "	13 46	5680	2360	3320	—7,8	15	4	—	(16) к
13 VIII	Херсон	15 12	5440	1250	4190	—7,1	10	21	11	(12) д, к
16 VIII	(18) Винница	14 56	5530	3280	2250	—7,2	9	(20) 11	9	(12) д, к
25 VIII	(19) Харьков	15 43	4790	1320	3470	—6,2	9	Кратковременный	—	(16) к
25 VIII	"	16 48	4580	1280	3300	—5,0	9	21	(20) Кратковременный	(21) к, д, к
16 IX	(22) Одесса	14 05	3540	770	2770	0,5	20	(20) Кратковременный	—	(16) к
24 IX	(23) Сухуми	10 24	3350	450	2900	—0,1	23	"	—	(16) к
26 IX	(24) Анапа	11 55	3360	1180	2180	—3,7	10	"	—	(16) к
26 IX	"	13 01	4160	800	3360	—6,8	12	32	32	(10) д

Key: (1). Date. (2). Area. (3). Time of gulf/bay (hour, min.). (4). deg. (5). The latent period of precipitation formation (min.). (6). General duration of precipitation (min.). (7). Duration of rain (min.). (8). Character of precipitation. (9). Kishinev. (10). d. (11). Krivoy Rog. (12). d, k. (13). Also. (14). k, d. (15). Precipitation were not. ([illegible]). k. (17). Kherson. (18). Vinnitsa. (19). Kharkov. (20). Short-term. (21). k, d, k. (22). Odessa. (23). Sukhumi. (24). Anapa.

Table 2. Frequency (o/o) of the values of the vertical extent of experimental and control clouds.

(1) Группа облаков	(2) Вертикальная мощность (км)						
	1.0–1.5	1.51–2.0	2.01–2.5	2.51–3.0	3.01–3.5	3.51–4.0	4.01–4.5
(3) Опытные . . .	—	—	27	27	27	7	12
(4) Контрольные .	3	3	21	40	30	3	—

Key: (1). Group of clouds. (2). Vertical extent (km). (3). Experimental. (4). Controls.

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If one assumes that these differences to a certain degree compensate for each other, then it is possible to count that the probability of the natural formation of precipitation of experimental and control clouds is identical and series in question are comparable between themselves.

Table 4 gives given data on precipitation from experimental and control clouds.

Thus, the experimental clouds gave precipitation noticeably more

frequently than controls ones. However, this difference is caused in essence by the increased frequency of precipitation of separate drops from experimental clouds, and the frequency of precipitation of rain in both groups of clouds is approximately identical.

It is of also interest to compare the duration of precipitation from the clouds being investigated. The general duration of precipitation (including precipitation of separate drops) it comprises in average/mean 17 min. of experimental and 18 min. of control clouds, the duration of precipitation of rain 17 min. of both groups of clouds.

Thus, neither in the number of cases of precipitation of rain nor in its duration of differences of experimental and control clouds it is reveal/detected that effect did not lead to an increase in the probability of precipitation of rain. The effect of effect on the process of precipitation formation in these cases could be revealed in the intensification of rain; however, this from data of visual observations reveal/detect could not.

However, the number of cases of precipitation of separate drops of experimental clouds is noticeably more than in controls. This fact can serve as the only index of the effect of actions. Apparently, in a number of cases with the application/use of the method being

investigated it was possible to cause precipitation of separate drops; however, these settlings are not of practical use, especially as their part evaporated with incidence/drop in subcloud layer. It must be noted that the effects of effect on the reduction processes of the water supply of cloud is not assumed, but the one-time water supply of Cumulus congestus clouds is insufficient for obtaining essential precipitation.

It is possible to assume that the effect PAV affects the dynamics of cumulus cloud. This they indicate that the authors of article [3].

Table 3. Frequency (o/o) of the values of temperature at the level of effect of experimental and control clouds.

(1) Группа облаков	(2) Температура на уровне воздействия (град.)				
	>0	−0.1—5	−5.1—10	−10.1—15	<−15
(3) Опытные	7	33	47	13	—
(4) Контрольные	—	27	61	9	3

Key: (1). Company of clouds. (2). Temperature at the level of effect (deg.). (3). Experimental. (4). Controls.

Table 4. Frequency (o/o) of the number of cases with the precipitation of different intensity of experimental and control clouds.

(1) Группа облаков	(2) Без осадков	(3) С осадками	(4) Отдельные капли	(5) Слабый дождь
(6) Опытные	13	87	40	47
(7) Контрольные	33	67	22	45

Key: (1). Group of clouds. (2). Without precipitation. (3). With precipitation. (4). Separate drops. (5). Weak rain. (6). Experimental. (7) Controls.

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Unfortunately, during the execution of the experiments to carry out systematic observations of the evolution of clouds it was not represented possible. In a number of cases, it was possible to note time of the initiation of the fracture of cloud. Up to the torque/moment of the termination of precipitation, all clouds were located in the stage of destruction. The noticeable differences in the character of the evolution of experimental and control clouds are not reveal/detected; however, for final conclusions are necessary supplementary investigations.

The made analysis makes it possible to assert that with the aid of the method being investigated in a number of cases it is possible to cause precipitation from convective clouds; however, to obtain virtually significant amount of precipitation from the clouds of the investigated range, obviously, on is represented possible, since the method does not provide for effect on the processes of the regeneration of moisture in cloud. Checking the effectiveness of method on the clouds of larger vertical power/thickness requires the setting of special investigations.

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